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Research cooperation

Between charisma and heuristics: four styles of interdisciplinarity

Martin Lengwiler

The paper examines the practices of interdisciplinary research projects in nine extra-university research institutions in Germany. The research fields of these institutions include representative fields of current interdisciplinary research, such as climate change research, environmental studies, organizational research, and area studies. The analysis shows that the outcome of interdisciplinary research cooperation depends upon the micro-organization of research practices. There is, however, no singular recipe for a successful cooperation. Instead, the case studies show a multiplicity of adequate "styles of interdisciplinarity": methodological, charismatic, heuristic and pragmatic interdisciplinarity. The differences between them depend upon the organizational and epistemic conditions of research practices.

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RECENT SCHOLARSHIP on interdisciplinarity has mainly focused on epistemological and conceptual issues, often marked by more or less explicit normative assumptions. In the tradition of the classic studies by the OECD (1972) for example, interdisciplinarity is often equated with innovation in research (Klein, 1990: 27ff). Studies on interdisciplinarity also try to differentiate multiple degrees of interdisciplinary research cooperation in terms of the epistemic qualities of the knowledge produced. Thus, different forms of interdisciplinarity are identified according to their degree of epistemic integration on a methodological or a theoretical level. Recent studies suggest different concepts for interdisciplinary cooperation, such as "multidisciplinarity" (defined as cooperation with a low degree of exchange between disciplines, not enough to count as interdisciplinarity), "transdisciplinarity" (cooperation beyond disciplinary qualifications, driven by the demands of practice contexts), "interdisciplinarity" (defined specifically as cross-disciplinary cooperation feeding back into disciplinary knowledge), or more idiosyncratic concepts such as Heckhausen's "chimaera interdisciplinarity" (an alleged *inter*disciplinarity, but in fact no more than cooperation between subfields *within* a discipline; see Klein, 2001; Heckhausen, 1987).

In current debates, the concept of transdisciplinarity, a form of multidisciplinary cooperation determined by practical demands and involving scientific as well as non-scientific actors, attracts particular attention. For some authors, this form of cooperation epitomizes a new form of scientific knowledge production more consistent with the wider social and political needs for expert knowledge (Häberli *et al*, 2001; Klein, 2001; Gibbons and Nowotny, 2001).

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Martina Röbbecke, Dagmar Simon, Martin Lengwiler and Clemens Kraetsch, 2004. *Inter-Disziplinieren: Erfolgsbedingungen von Forschungskooperationen*. Berlin: Edition Sigma.

Compared with this epistemic debate, relatively little empirical work has been done on cooperative practices in interdisciplinary research. There are only a handful of empirical studies on interdisciplinarity, focusing mainly on single cases or specific research fields. Examples are the study by Grit Laudel (1999), examining two research programmes within a single field in natural sciences: the case studies in the volume on *Practicing Interdisciplinarity* edited by Peter Weingart and Nico Stehr (2000); or the study on research practices in environmental consultancies by Michael Guggenheim (2005). The current understanding of interdisciplinary research practices is still sketchy with little comparative and generalizing analysis available.

This article is based upon a study of interdisciplinary research practices in extra-university research institutions in Germany, conducted by Martina Roebbecke, Dagmar Simon, Martin Lengwiler and Clemens Kraetsch.[1] In our study, we defined the term 'interdisciplinarity' in a broad sense, embracing different forms of multi-, inter- or transdisciplinarity (as defined above) in a big tent concept. We abandoned the traditional distinctions between multi-, inter- and transdisciplinarity for our study, because they seemed inadequate for analyzing our empirical data. For example, the qualities of cooperative research reflected in the distinction between inter- and multidisciplinarity represent only the cognitive dimension of interdisciplinary research practices. However, apart from the cognitive level, empirical interdisciplinary practices are also shaped to a considerable extent by institutional and organizational conditions. Moreover, confronted with the empirical data, the traditional concepts turned out to be unsuitable (presumably because of their normative subtext); most of the cooperative research practices we studied seemed to be some mixture of inter-, multi- and transdisciplinarity.

Finally we wanted to abandon the normative subtext of some studies on inter- or transdisciplinarity. Instead of looking for the one 'successful' way of enhancing interdisciplinary cooperation, our basic assumption was to analyze interdisciplinary practices as a field of multiple styles of practices each with its own potentials and problems. This notion of a variety of "styles of interdisciplinarity" is borrowed from Ludwik Fleck's concept of "thought-styles" (Fleck, 1979). From this starting hypothesis, we tried to develop a new terminology more appropriate for analyzing empirical practices in interdisciplinary cooperation.

We investigated a comparatively broad field of interdisciplinary research practices, examining nine research institutes, all specifically engaged in interdisciplinary research but focusing on different thematic fields and with different institutional affiliations. All institutes belong to the extra-university research sector in Germany, a significant part of the German research system comparable in size to the university research system. The spectrum of extra-university institutions is borne by four pillars, partly dedicated to a specific research type, partly following a particular funding model: the Max Planck Society, committed to basic research; the Fraunhofer Society, committed to applied or contract research; the Helmholtz Association, composed of the traditional big science institutions (nuclear research, aerospace research, environmental research) mostly founded in the 1960s and 1970s; and the Leibniz Association, composed of institutes with different research orientations but a common financial structure (50% paid by the federal government, 50% by state governments). Examining extra-university institutes is an obvious choice, since interdisciplinary research in Germany is traditionally stronger in the extra-university sector than at the mainly disciplinary universities.

Our selection of institutes includes cases from all extra-university pillars: three Max Planck, three Leibniz, two Fraunhofer institutes and one Helmholtz center. Methodologically, our study is based upon analyzing interviews and document data and not on ethno-methodological approaches such as participant observation. In all, we conducted 82 semi-structured interviews between October 2001 and November 2002. The questions focused on general experience and specific problems of interdisciplinary research practices, rather than the cognitive characteristics of the research products. This included questions about how interdisciplinary groups collaborated, how and to what extent collaboration was organized, what practical problems occurred, and what measures were taken to resolve these problems.

This methodological focus on interview and document analysis allows us to follow research practices and the day-to-day cooperation in interdisciplinary research projects only through the eyes of the researchers involved. To obtain a comprehensive picture of collaborators' experience in interdisciplinary projects, we interviewed employees of the institutes on all staff levels, including representatives from both administrative and scientific staff, and collaborators in superior as well as inferior positions.

In each case we were able to talk with several researchers directly involved in the day-to-day business of interdisciplinary projects. The following article summarizes the main argument of our study. For lack of space, I will concentrate on analyzing the organizational and cognitive conditions of four styles of interdisciplinary research practices.[2]

Typology for analysis

It is clear that with this institutional focus our study would primarily reflect institutional and organizational influences on interdisciplinary practices and only secondarily the cognitive factors. However, to enable reflection on the cognitive dimension of interdisciplinarity, we also selected institutes representing different research fields prevalent in interdisciplinary research, such as climate change research, environmental research, area studies or organizational studies. In this sense, the following analysis is based upon the assumption that research practices are determined by two external factors: organizational conditions and cognitive conditions.

The first part of this assumption, the organizational determination of research practices, is self-evident. It is what most science and technology studies (STS) have consistently argued: that the production of scientific knowledge depends on the social and organizational context within which it is undertaken. The second part of the hypothesis — the dependence of research practices on cognitive conditions — is more recent in STS literature. It means that practices in research also differ according to the cognitive qualities of the research field (and not its social organization). Such a line of argument is inherent, for example, in Karin Knorr Cetina's concept of "epistemic cultures" and in studies based upon her approach (Knorr Cetina, 1999; for empirical studies with a similar approach, see: Hohn, 1998; Heintz, 2000; Heintz *et al*, 2004).

To allow for a typology of research practices and after validating a series of organizational and cognitive factors, we formalized our assumptions by drawing a figure with two specific independent variables, which turned out to be particularly effective for shaping interdisciplinary cooperation:

1. *the degree of organization* of interdisciplinary research representing the main organizational variable; and
2. *the degree of coupling of cognitive research aspects* as the main cognitive variable.

As the dependent variable, we expected highly differentiated types of interdisciplinary research practices (see Figure 1).[3]

In specifying the two independent variables we drew on work in organizational sociology and the sociology of science. To assess the degree of organization, we considered different mechanisms for structuring interdisciplinary research practices, such as the centralization (or decentralization) of responsibilities in an institute, the formalization and hierarchization of research activities and communicative processes, or the specific governance arrangements for research projects (Mayntz, 1985: 36f). We also took into account the extent to which research projects in an institute are externally determined (and structured), for example by third-party funding institutions or by obligations from evaluation committees. We also considered social differentiation in an institute, for example the extent to which interdisciplinary research groups were formally (or informally) organized.

In a loosely coupled research field, investigation is in constant flux, scientists individually pursue different research purposes, and knowledge gains are not accumulated

In assessing the degree of cognitive coupling, we referred to the work of Richard Whitley. Whitley defines the degree of cognitive coupling in two dimensions: the mutual dependence between disciplines of a research field and the degree of task uncertainty of the research (Whitley, 1984: 158f; for a more recent adaptation of Whitley's concept, see: Hohn, 1998: 57f). The concept of mutual dependence is particularly relevant for our cases. It means both the social interdependence of research activities and the analytical integration of theoretical approaches, methods and empirical results (Whitley, 1984: 158–164). In a loosely coupled research field, investigation is in constant flux, scientists individually pursue different research purposes, and knowledge gains are not accumulated. There is no stable consent between disciplines about priorities or about relevant paradigms — a situation that Whitley calls "fragmented adhocracy", manifest for example in business studies (Whitley, 1984: 158; Hohn, 1998: 57f). A high degree of coupling is marked by high cognitive aggregation and integration of the research field; we find coordinated research strategies, a cumulative process of knowledge gains, with an integrated development of theoretical and methodological standards (Hohn, 1998: 57).

In our study, we examined three indicators to measure the degree of cognitive coupling:

1. the variety and range of the disciplines represented in one institute;
2. the institute's claim for methodological and theoretical integration in its research; and
3. the consistency and integration of the international research network of an institute.

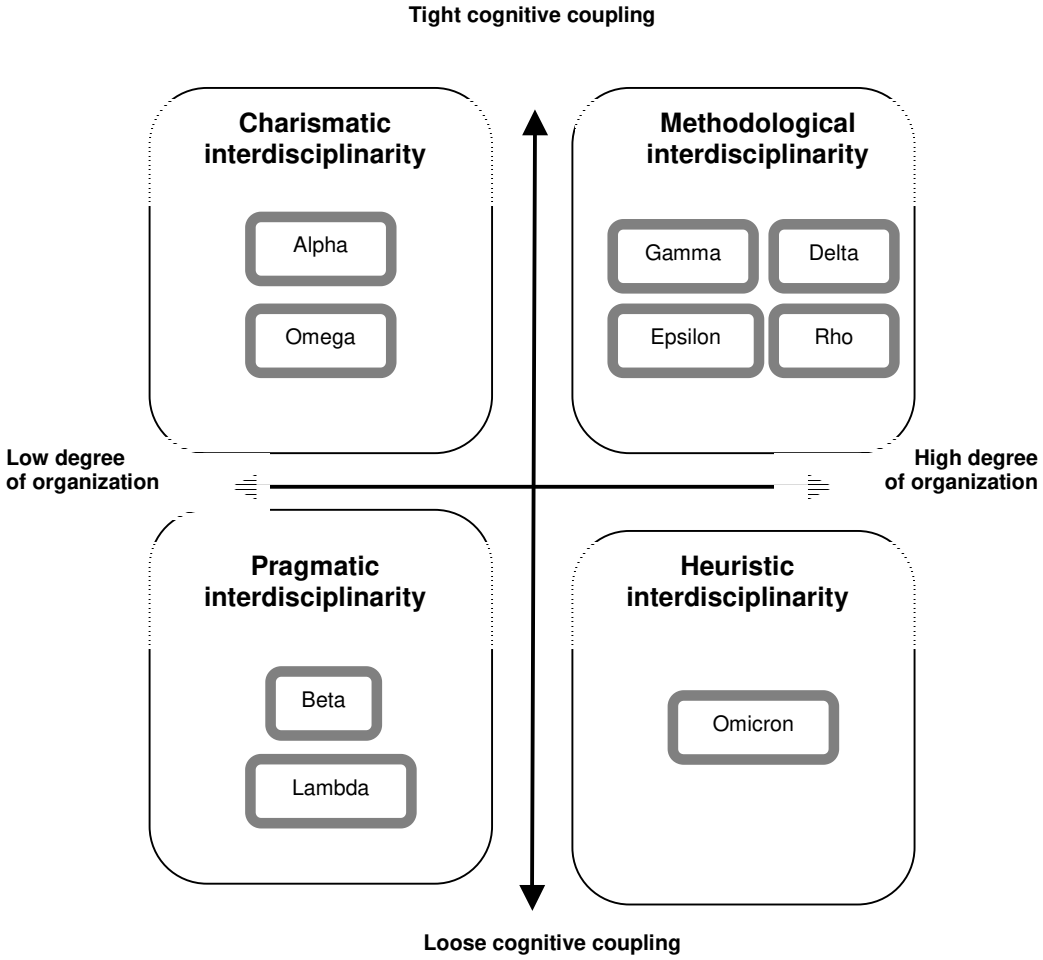

Figure 1. Analytical model for a typology of interdisciplinary research styles
Note: the Greek letters represent anonymized nouns for the nine research institutions examined in the study's sample.

Based upon the two independent variables, we designed a quadrant model for analyzing interdisciplinary research practices. The model distinguishes four types of condition determining interdisciplinarity:

1. a high degree of organization together with a high degree of cognitive coupling;
2. a high degree of organization combined with a low degree of cognitive coupling;
3. a low degree of organization associated with a high degree of cognitive coupling; and
4. both a low degree of organization and a low degree of cognitive coupling.

Taking the institutions under study as the main empirical entity, we arranged the nine research institutes of our sample according to the four research types suggested in our model (see Figure 1). We then tried to find indications for a common type of interdisciplinary cooperation within each of the quadrants of the model. The analysis of our material, we would argue, offers enough evidence to support our assumption that organizational and cognitive conditions do indeed determine distinct types of interdisciplinary research style. Accordingly, we distinguished four styles of interdisciplinarity to be described in the next few paragraphs: a methodological, a charismatic, a heuristic, and a pragmatic research style.

Methodological interdisciplinarity

The methodological style of interdisciplinarity is typically found in the fields of climate change and environmental research. It is marked by two characteristics:

1. a highly formalized structure of the institutes leading to a high degree of organization of the research projects;
2. a comparably consistent methodological and theoretical framework, leading to a tight cognitive coupling within interdisciplinary cooperations.

Remarkably, these cognitive and organizational conditions stabilize each other, leading to a comparably stringent form of interdisciplinarity. Differently from what might be expected, research cooperation does not suffer from the comparably

advanced formalization and organization of the research environment. On the contrary, most researchers in these highly organized institutes stressed that they did not see the high degree of organization as restricting or contradicting their scientific autonomy but rather as a supportive mechanism for their work. Moreover, the cognitive preconditions and features of the research field are particularly formative for the characteristics of the research style. In both fields — climate change and environmental research — the consistency of the research style is due to the particular significance of modelling approaches current in these fields. Thus, the modelling approach offers an appropriate cognitive basis for an organized interdisciplinary cooperation.

To understand how it is possible that cognitive and organizational conditions for interdisciplinary projects can be productive without restricting the autonomy of scientists, we will first analyze the formal organizational structure of the institutes and then the cognitive characteristics of their research fields (for the cognitive conditions, see next section). All four institutes with methodological interdisciplinarity dispose of a variety of organizational structures to foster interdisciplinary communication: interdisciplinary seminars, working groups, or formal interdisciplinary processes for developing new and innovative research questions. These organizational conditions are often specifically designed to provide incentives for enhancing research cooperation across disciplinary boundaries. One of the most radical incentives, and a good example for the effects of organizational instruments, is the implementation of a 'matrix' organization on the level of the institute (found in two of the four methodological institutes).

A matrix organization is a rearrangement of a departmental structure traditionally prevalent in extra-university research institutions in Germany. This structure divides the institution into research fields, each assigned to a department, often equivalent to a specific disciplinary approach. Funding is divided along departmental lines and then distributed within departments. Research projects are also conducted within departments. A strong departmental tradition often leads to the pillorization of the institution; the potential for innovative cross-departmental communication and interaction is hardly exploited.

A matrix organization basically seeks to compensate for the lack of cross-cutting potential in a pillorized departmental structure by enhancing cross-sectional interaction by organizational means. In the case of the Delta institute, the matrix element consisted of a series of cross-sectional research groups, each focusing on innovative themes. The choice of topics was made after a participatory, bottom-up process involving all members of the institute's scientific staff. The entire staff was asked in the framework of a competition to suggest ideas for innovative research fields. The large number of suggestions was narrowed down to seven topics that formed the thematic nucleus for the new matrix groups. These newly founded matrix groups consisted of members of the old department — the matrix posts were occupied as dual mandates, with members retaining their previous departmental positions. The matrix groups were allowed to suggest and conduct their own research projects; the life-span of the groups was limited to 10 years, that of the groups to one to four years. All matrix groups were regularly reviewed and, if the review was negative, terminated.

To strengthen the influence of matrix groups *vis-à-vis* departments, the Delta institute introduced a new rule committing all departmental projects to relate in some way to at least one matrix-group project. The explicit idea of the matrix groups was to increase interdisciplinary cooperation. By limiting the life-span of the groups, the institute management hoped regularly to build new social networks over and beyond traditional departmental groups. By stipulating that departmental projects were to relate to matrix-group topics, the institute also hoped to establish a mechanism for focusing the institute's research themes more sharply and in a more manageable way. The institute also started a continuous, formalized review of the new organizational structure by devoting one matrix group solely to theoretical, methodological and organization cultural questions of interdisciplinary cooperation. This methodological matrix group became something like a custodian of the Delta institute's scientific identity.

By committing departments to relate thematically to matrix groups in their research, the directors of the Delta institute basically turned the old organizational structure of innovation upside down. As a result, departments lost considerable influence over the institute's scientific agenda. The agenda-setting process in the Delta institute now mainly takes place within matrix groups. Departments, in contrast, currently focus more on imparting disciplinary qualifications to Delta staff, whereas their input in developing new research projects has declined. Departments still have full administrative competences, for example in personnel management. One interviewee pointedly remarked: "If you want to take it to the extreme, let's say that sometimes we [the departments] are merely there to sign the applications for leave" (interview with Stefan M; Delta).

Whereas the power of the matrix groups in the Delta institute was based upon their thematic influence, the new cross-cutting entities in the other matrix-structured institute, Epsilon, also gained financial power. The Epsilon institute offers the most radical case of organizational support for interdisciplinary cooperation in our sample. Interdisciplinarity is enhanced primarily by financial incentives. The matrix reform in the Epsilon institute was implemented in two steps. First, the thematic competence for the institute's research programmes was transferred from the department to newly founded 'cross-sectional areas', consisting of old departmental

personnel. The mandate of the cross-sectional areas was to develop research projects beyond the departmental organization for which they would subsequently have to apply for funding by departments. Up to this point, the reform was similar to the Delta case.

However, the Epsilon management remained uneasy about the efficacy of a merely content-oriented matrix structure. It was particularly afraid that a shift on the thematic level alone would not suffice to force departments to change their research strategies and cooperate more intensely across disciplinary borders. In a second step, therefore, the Epsilon management introduced a new key for distributing the financial resources of the institute. Thus 60% of all research funding was channelled directly to the cross-sectional areas; the other 40% remained with departments (meaning, in effect, departments' funding was reduced from 100% to 40% of the research budget). This division of funding was discussed among the staff; eventually most involved found it a fair solution. An important argument for fostering the cross-section areas was that, since they had been set up, they had been much more successful in acquiring external research funding. In the light of this success, it was considered a legitimate measure to broaden their financial competence within the institute.

This reform has fundamentally changed power relations within the Epsilon institute. Although departments are still responsible for a majority of research projects, amounting to more than the 40% of the funding at their disposition, they now have to apply to the new cross-section areas for research funding. At first, this application process was seen as a merely formal procedure with no real danger of selection. However, the cross-section areas have recently started to grant funding more selectively and actively to criticize some departmental research projects for lack of quality. At the time of our interviews, the turning point had just been reached with the first departmental projects actually being rejected by the cross-section areas. The director of the institute commented at the time that, "for the first time it became clear to the staff what the new [division of financial competences] actually meant" (interview with Johann W; Epsilon).

Clearly, implementation of a matrix structure in the Epsilon institute has gone further than in Delta. As a result of their increased financial responsibilities, matrix groups in Epsilon have also acquired administrative competencies from departments. Although the departments formally kept their administrative authority, practice showed that they were unable to act without the implicit consent of the cross-section areas. The cross-section areas have thus even gained influence over the hiring of new staff and over the choice of personnel for all projects in the institute. Departments have started checking regularly with cross-section areas before hiring new staff.

Although the introduction of matrix elements into the institutes' formal organization has brought new formal restrictions for conducting research projects (for example, the obligation to relate projects thematically to cross-section topics or to apply to cross-section groups for funding), the scientific staff of both institutes predominantly agree that the new structure does not restrict their scientific autonomy. On the contrary, most interviewees see the reforms as enhancing the innovative potentials of the institute's research projects. A crucial factor for this wider acceptance of a formally organized research style is that, in both institutes, the new formal structure has been developed in a partly participatory procedure, which allowed the staff involved to shape some of the new rules in a form of self-government.

Cognitive conditions

It seems that the acceptance of organizational restrictions in research practices, as illustrated by the methodological institutes, is also based upon cognitive premises and the day-to-day practices specific to the research fields of environmental and climate change research. As mentioned above, the modelling approach is constitutive to both research fields. Modelling is a particularly formalized research approach. Thus, it is no coincidence that researchers involved in modelling show an affinity and a particular understanding for organized forms of research.

On the practical level, modelling means that researchers have to combine the disciplinary components of their colleagues into an integrated model (Merz, 1999). Modelling has already been an established method to mediate theoretical assumptions and empirical data in disciplines such as mathematics and physics (Morrison and Morgan, 1999). Since the 1960s, modelling, combined with computer simulation, has become a defining method for particle physics and climate research (Sismondo, 1999). Until the present day, modelling in climate research has stood in the tradition of physics; some climate researchers still see the physical approach as the "gold standard" of their work (interview with Bernd A; Gamma). Originally, climate models were a combination of two partial physical models, one for

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the atmosphere, and one for the oceans. In recent years, traditional climate models have been expanded to include models for the biosphere and the chemistry of the atmosphere; there are current endeavours to integrate these partial models and enlarge them to include models for socio-economic processes (Röbbecke *et al*, 2004: 52f, 56f).

This methodological legacy associated with the modelling approach is important for understanding the day-to-day practices of interdisciplinary cooperation in climate research. In the institutes of our sample, particularly in the climate change institutes Gamma, Delta and Rho, the modelling process is split into two stages. The first stage consists of the theoretical construction of a new model, which then, in the second stage, is applied — that is, fed with empirical data — and gradually further developed. The application phase itself consists of two different processes: an experimental process focusing on collecting and measuring empirical data, and a process of model development, in which the model is fed with the empirical data and revised according to the latest experimental measurement. Both processes, the experimental process and model development, are conducted parallel to and in interaction with each other.

The high cognitive coupling in methodological interdisciplinarity is provided by what climate change researchers call the "coupling" of disciplinary data or model elements into an encompassing model, a key process in the development of a model. In the 1980s, climate models traditionally consisted of two physical sub-models: an atmospheric and an ocean model. In recent years, sub-models for the biosphere and for the chemistry of the atmosphere have been added. Eventually, these predominantly physical models (indeed, physics counts as the core discipline in climate change modelling) were combined with biogeochemical sub-models (namely models for the interaction with biospheric, hydrospheric and atmospheric processes) in order to develop a global climate model. The structured integration of new sub-models is an ongoing process. Currently, a hot topic in climate change research is the integration of models for socio-economic processes, a task in which, for example, the Delta institute is specializing.

The coupling of different sub-models in a common climate model is a highly formalized procedure based upon a mathematical calculation of the empirical data in the forms of algorithms and differential equations. An individual algorithm often concerns a very specific phenomenon, for which ultimately a single researcher can be responsible. At the time of our interviews, the Gamma institute, for example, was collaborating with an external fire ecologist. This specialist was responsible for calculating the specific data on atmospheric emissions caused by past forest fires — data that Gamma needed for its climate model. Another external collaborator was responsible for a specific microphysical process affecting a particular aerosol under specific conditions — thus helping to explain a particular form of emission. Gamma's task was to define the parameters for collecting the data and ultimately to feed the data into its models at predetermined interfaces. This highly developed division of labour reflects the radically specialized form of interdisciplinary collaboration in climate change research.

The scientists' acceptance of organizational facilities, such as a matrix structure, has to be explained in the light of this specialized cooperation on the cognitive level. The formalized mechanisms for the combination of disciplinary knowledge, as illustrated in the modelling approach, show that scientists in climate change or environmental research institutes are already accustomed to a highly structured form of cooperation on the cognitive level. Compared to these cognitive formalizations, the organizational means are just a minor step forward and do not contradict the pattern of research practices in the methodological style of interdisciplinarity.

Charismatic interdisciplinarity

The charismatic style of interdisciplinarity is found in institutes with a decentralized structure lacking the organizational elements for fostering interdisciplinary cooperation. On the level of research practices, the official structure of these institutes matters little. Researchers rely instead on personal contacts and informal networks. At the same time, the degree of cognitive coupling is still high, similar to that in methodological interdisciplinarity. Thus, interdisciplinary cooperation relies heavily on interaction on the cognitive level, for example on methodological or theoretical issues. One of the two instances of this type of interdisciplinarity, the Alpha institute, is indeed an institute for climate change research — albeit a much smaller, and therefore more informal, institution than the other three institutes in this research field (Gamma, Delta, Rho). The other case, Omega, is a social science institute with a strong minority of natural scientists; methodologically, its research is firmly based upon statistical approaches.

In both institutes, the low degree of organization was due to ongoing reorganization. The Alpha institute has been repeatedly reorganized over the past years; these reforms have been paralleled by a shrinking process due to the austerity policy of its parent organization, the Fraunhofer Society. Within three years, Alpha had to cut its staff by a quarter. As a result of this reorganization, the institute's staff has often manifested a stoic and disinterested attitude towards the formal organization of their work. One interviewee remarked that the organizational structure of Alpha tended to be short-lived and that people came to reconcile themselves with this continuously changing environment (interview with Hubert K; Alpha). In the Omega institute, the reason

for the low degree of organization was different. Omega was a newly founded institute still in the process of building up its full research capacity. The composition of the personnel was still in flux, the institute was also about to change location and move into a new building. Also, the Omega director committed his institute strictly to a hiring policy based on temporary contracts of three to five years — thus accelerating the continuous staff turnover in the institute. Finally, the founding director of Omega believed in a decentralized, informal management style:

> There are different kinds of leadership styles. There's some tradition in Germany for directors of Max Planck Institutes to be very authoritarian, to tell people what to do. And, I never do that, never … I very strongly believe that all important decisions should be reached by consensus. So I never tell anybody to do anything … If somebody doesn't agree, then I don't do anything. (interview with Josef K; Omega)

Under these circumstances, interdisciplinary cooperation depended mainly on informal and personal interaction. Work was done in small, often self-organized teams; communication was based upon informal networks. Both institutes were rather small — an aspect often stressed in interviews. One researcher felt that explicit measures supporting interdisciplinarity were not necessary, because the institute was so small that "people knew each other" (interview with Eva M; Alpha). Research-related communication loci included cafeterias, sport groups, works outings or birthday parties. Also, when the interviewees had to describe the preconditions for effective interdisciplinary cooperation, they stressed "weak" and personality-related competences, such as openness towards innovation, interest for other people and their disciplinary background, patience, flexibility in social interaction, and generally an honest, cooperative and altruistic attitude. In the words of one researcher, interdisciplinarity has to be a "really internalized" quality (interview with Sven P; Omega). Interviewees also stressed the significance of an informal approach for the settlement of personal tensions or conflicts in interdisciplinary groups. "These are personal matters; in these cases you have to talk to people, most suitably in the evening over a glass of beer" (interview with Franz A; Alpha).

A noticeable characteristic of these institutes is that interviewees tended to credit the respective director with charismatic authority — a phenomenon which we have described as "charismatic" style of interdisciplinarity. One researcher from the Alpha institute stated: "We certainly have an official structure, but in fact during the time when I was conducting these [interdisciplinary] joint projects, this official level no longer played any role. Basically, there was just Herr M (the institute's director) initiating the project" (interview with Peter F; Alpha).

Also at Alpha, most researchers had a highly personalized understanding of the decision-making mechanisms of their institute. A typical remark was that "in our institute, quite a lot is decided by the 'chief'" (interview with Eva M; Alpha). The term 'chief' for the scientific director was not a coincidence; most staff members used it in preference to his name. The influence of the director of Alpha was regarded as extramundane and omnipresent, recalling the Weberian concept of charismatic authority. Some interviewees stressed his outstanding helpfulness: "I have to say, our 'chief', when he sees that something is taking a positive turn, he is extremely supportive – I must stress this" (interview with Franz A; Alpha) Others refer to his pervasive influence in elaborating research proposals to become successful applications: he was said to have "the right touch" and the "vision" for successful interdisciplinary projects (interview with Peter F; Alpha).

The advantage of the charismatic style of interdisciplinarity is that it produces high intrinsic motivation among the staff based upon trust in leading figures. Under such conditions, there is large scope for creative forms of cooperation, thanks not least of all to a low degree of organization. With reference to Max Weber's notion of charismatic authority, we use the concept of charisma to mean an extramundane, non-bureaucratic form of exercising power (Gebhard, 1993a: 1–4). In our cases, however — unlike in Weber, for whom charisma was the antithesis to a rational-bureaucratic form of authority — charismatic authority is exercised in context of scientific institutions. As Shmuel Eisenstadt and Edward Shils have argued in their classic critique of Weber, charismatic authority is not restricted to premodern or pre-rational societies; it can be incorporated as a power dimension in modern bureaucratized institutions and societies – albeit in secularized form (Shils, 1982; Eisenstadt, 1968; Gebhardt, 1993a: 2, 1993b: 47–50).

The significance of charismatic authority in institutes such as Alpha or Omega has to be explained sociologically as an effect of the actual power of leading positions in academic institutions. Particularly in institutes like Alpha or Omega, the power of the directors goes far beyond specific administrative and staff-related authority. Both directors put their stamp on the institutes; one was the founding director, the other a long-term director responsible for building up most of the institute's international reputation. Thus, most staff members were personally hired by the current directors. Moreover, the Omega institute belongs to the Max Planck Society that fosters the so-called "Harnack principle", named after one of the founders of the Kaiser Wilhelm Society, the direct precursor of the Max Planck Society. According to the Harnack principle, the scientific director of a Max Planck institute is given

When a director with charismatic authorities is absent, interdisciplinary cooperation loses its integrating factor and risks disintegrating into parallel multidisciplinary projects

almost all-embracing powers to define the scientific direction of the institute and to recruit the appropriate staff (Vierhaus, 1996; Gerwin, 1996). In other words, charismatic authority merely reflects the hierarchical order of scientific institutions of this type.

The downside of charismatic interdisciplinarity is its dependence on the presence of the leading figures and successive instability. When a director with charismatic authorities is absent, interdisciplinary cooperation loses its integrating factor and risks disintegrating into parallel multidisciplinary projects. In the Omega institute, the staff regarded the research seminar as the main locus for interdisciplinary exchange — of course under the guidance of the director. However, the seminar lost its meaning as soon as the director was on leave or on a business trip. "And when he [the director] isn't there, we really do nothing; if anything is on then [at the seminar], I'm not keen to go there. It is really him that holds our institute together. If he isn't there, we are a far cry from the whole interdisciplinarity thing" (interview with Paul D; Omega).

Heuristic interdisciplinarity

In a way, the heuristic style of interdisciplinarity is the opposite of the charismatic style. Contrary to charismatic interdisciplinarity, research projects are highly organized. In the single institute (Omicron), in which we detected a heuristic style, most projects were applied or contract research projects. Under these circumstances, research was subject to great time pressure and to budget constraints. Also, the market conditions and customer expectations to which applied research projects are exposed are quickly changing. Accordingly, the disciplinary composition of projects as well as the methodological approach has to adapt to changing market expectations and has difficulty maintaining coherence. Thus, in contrast to charismatic interdisciplinarity, the cognitive coupling of a heuristic style of interdisciplinarity tends to be weak.

Unlike in other forms of interdisciplinarity, the outcome of the heuristic style does not depend primarily on the combination of disciplinary qualifications. At least as important are heuristic and pragmatic qualifications like project experience, problem-solving skills and management qualities. Only these heuristic qualifications can guarantee that projects are successfully completed despite temporal and financial constraints. In the case of Omicron, the typical contract project lasts about six months, much less than the usual two to three years offered by publicly funded institutions. Advanced management and controlling techniques are therefore crucial for the success of short-term projects and are applied in all Omicron projects. Also, a newly appointed Omicron researcher undergoes a systematic training programme focused on project management, presentation techniques and time management, rather than on disciplinary qualifications. Senior staff members are offered an advanced training programme, including, for example, courses on project control and conflict management.

Disciplinary qualifications are not only less important than management skills; they are also gradually transformed into a pragmatic, application-oriented knowledge that has lost its distinct disciplinary contours. Most interviewees in Omicron point to the limitations of disciplinary qualifications for their day-to-day work in research projects. For them, their disciplinary education is not the single and crucial qualification; it counts only in combination with the practical experience of a researcher gathered in the course of several projects. These pragmatic skills have the status of "tacit knowledge", difficult to teach explicitly (Collins, 2001). One interviewee remarked that a good researcher has to have an intimate experience base, particularly about the customers of the institute. This qualification, he said, could be acquired only by practical experience. A good researcher would have to know how customers ticked (interview with Dietmar E; Omicron). To teach these tacit skills, Omicron has institutionalized a coaching system under which every junior researcher is personally accompanied and trained by a senior coach over the first years working at Omicron.

A problematic aspect of heuristic interdisciplinarity is the difficulty of publication. For several reasons, Omicron researchers have a hard time publishing their research results. One reason is practical: because of time pressure and the need to present results in a customer-oriented form, researchers find it difficult to take the leisure for writing and revising articles to be published in peer-reviewed journals. Another reason is structural: the research field of the Omicron institute (organizational studies) offers few academic journals that publish articles with an interdisciplinary background — a typical phenomenon for new interdisciplinary research fields.[4] Thus, Omicron has hardly any junior scientists working on a PhD, despite a specific support programme for dissertation projects in the institute. Habilitation projects and professorial careers are even less frequent, indeed a rare exception. The normal career of Omicron scientists is to work for a few years as a junior scientist before leaving the institute for a better-paid business job.

The heuristic style of interdisciplinarity has a lot in common with the 'transdisciplinary' research type that is often seen as an innovative research model. Recent work in science studies has repeatedly postulated a trend towards a new mode of knowledge production beyond the old linear mode of basic innovation in science, which would then be transferred beyond academic institutions to the context of application. In this sense, transdisciplinarity means an application- or practice-driven form of knowledge production, beyond disciplinary traditions, promising a socially more "robust" form of expertise (Nowotny et al., 2003; critically: Pestre, 2003).

Against the backdrop of heuristic interdisciplinarity, the positive connotations of the concept of transdisciplinarity have to be put into perspective. Close cooperation with non-academic partners, occurring in most Omicron projects, certainly makes research results better applicable. But as in the case study by Guggenheim (see this issue of *Science and Public Policy*, pp. 411–421), there are signs of a "proceduralisation" (Guggenheim) of transdisciplinary research practices, meaning that the focus of everyday work practices shifts from content-related to form-related matters. In such a context, management qualifications become at least as important as disciplinary qualifications (for a similar critique of managerial approaches in transdisciplinary research: see article by Maasen and Lieven in this issue of *Science and Public Policy*, pp. 399–410).

Moreover, the academic careers of junior scientists can also be handicapped by transdisciplinary research practices. In addition, the proximity to actors outside science not only interferes with the career plans of individual academics, it can also marginalize the entire research field within the academic system. In some research areas, such as in climate change research, this marginal position against established disciplinary traditions turned out to be a temporary phase in the establishment of a now respected (and to some extent discipline-like) research field. Whether this is also possible in the case of organizational studies and the Omicron institute remains to be seen. Permanent marginalization in the field is, at least potentially, reinforced not least of all by the disadvantages of an application-oriented, transdisciplinary research approach.

Pragmatic interdisciplinarity

The pragmatic style of *interdisciplinarity* is the most fragile of the four research types – its characteristics will only be briefly summarized. In both pragmatic style cases, the Beta and Lambda institutes, interdisciplinary cooperation is neither explicitly supported nor enhanced by organizational means. Also on the cognitive level, there are no integrative incentives or mechanisms comparable to the other institutes of the sample. Both institutes lack an encompassing theoretical approach, imposed for example by scientific directors. Although both directors have a personal research agenda with a specific theoretical aim, both institutes manifest strong opposition to methodological and theoretical integration and a well-established decentralized research culture prohibiting decisive influence by a single person as to be found in charismatic interdisciplinarity. Theoretical and methodological approaches, as well as research topics, vary from department to department in Beta and Lambda. Interdisciplinary cooperation is practised only to a limited extent and within the boundaries of a department. The reasons for engaging in interdisciplinary cooperation are mainly external or pragmatic, for example, the need to fulfil the requirements of funding institutions or evaluation committees. Most interdisciplinary projects are therefore based on *ad hoc* cooperation.

Under these circumstances, it is not surprising that outright opposition to the idea of interdisciplinary cooperation was strongest in the Beta and Lambda institutes. One interviewee was particularly blunt:

> Well, I don't like the concept of interdisciplinarity at all, because it is a completely artificial formula. The fictive idea that there's such a thing as interdisciplinarity should be dumped in the dustbin of history or the wastepaper basket … The whole thing is nothing more than a lie. (interview with Heinrich D; Lambda)

Conclusion

It has not been the intention of this article to offer a single recipe or a "gold standard" for successful interdisciplinary cooperation. It argues rather for a multiplicity of interdisciplinarity styles, each with its own mechanisms, potentials and problems and each depending upon the organizational and epistemic conditions of the specific research field.

The article has formalized these organizational and epistemic factors in a quadrant model with two independent variables (the degree of organization and the degree of cognitive coupling). However, contrary to what this model might insinuate, we do not posit any deterministic correlation between organizational and epistemic conditions on the one hand and the style of interdisciplinarity on the other — for example that an institute with a high degree of organization and a high cognitive coupling would inevitably produce a methodological style of interdisciplinarity. Organizational and cognitive conditions do account for a variety of styles, but these styles often overlap and merge in one and the same institute. In the Delta institute, for example (allocated to the methodological style) we also found evidence for charismatic interdisciplinarity. Similarly, the Alpha institute, representing the charismatic style, also partly practises methodological interdisciplinarity. Thus, the four styles of interdisciplinarity outlined in the paper represent ideal

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types; in reality, numerous mixed forms and overlaps are possible. Likewise, the four types illustrate some common but not all imaginable forms of interdisciplinary research practices.

The study also indicates that support for interdisciplinary cooperation by organizational means can be crucial for enabling collaborative research. In the interviews conducted, scientists usually focused on the cognitive aspects of interdisciplinary collaboration, treating organizational circumstances as a minor point. This rhetoric reflects a traditional understanding of science, based upon the autonomy of individual researchers as the driving force of innovation. However, this classical image of science is a far cry from the everyday practices we encountered in the institutes under study. Organizational means such as new research structures cutting across disciplinary departmental pillars increased the financial responsibilities of interdisciplinary teams against their disciplinary colleagues, or the formalization of management and controlling procedures for research projects — all these tools usually enhanced the capacities of interdisciplinary research projects.

However, it is difficult to identify universally valid rules of how organizational means can change the success rate of interdisciplinary practices. The impact of organization differs according to the context of interdisciplinary research projects. Organizational instruments to enhance interdisciplinary cooperation can be selected only according to the context in which they are to be applied. For example, the effect of organizational means on interdisciplinary research varies with the characteristics of the cognitive field or the "epistemic culture" (Knorr Cetina, 1999). The above analysis shows that in institutes dealing with a cognitively well-structured research field, organizational constraints on interdisciplinary cooperation are well accepted by the researchers involved. Typical examples are well-focused, problem-oriented research fields like climate change or organizational studies, where we found an established consensus about methodological and theoretical approaches.

In more heterogeneous or even diffuse research fields, like the institutes for area studies, the acceptance of organizational constraints was much lower. In some cases, attempts to organize interdisciplinary research encountered outright opposition and eventually failed. Accordingly, organizational means are not helpful *per se* in enabling or fostering interdisciplinary cooperation, they also depend on an "organization-friendly" epistemic culture (a point supported by the case studies by Pregernig, see his article in this issue of *Science and Public Policy*, pp. 445–455).

Moreover, if organizational means were introduced in a participatory or a discrete, implicit way, they were not necessarily seen as challenging the agency of individual researchers. One example for such a participatory process was the development of matrix structures in the Delta and Epsilon institutes. In a comparable study, Sabine Maasen spoke of the "magic" effect of "organized self-organization" as a "golden rule" for interdisciplinary cooperation: "Although indispensable, they [the organizational activities] have to be as implicit and as invisible as possible. They have to be part of the group's self-organized *procedure* to produce a stimulating atmosphere" (Maasen, 2000: 190).

Despite the significance of organizational instruments, informal opportunities for interaction and communication are equally important for interdisciplinary projects. The informal level is particularly useful for reducing the often advanced degree of complexity and uncertainness in interdisciplinary contexts. In this sense, interdisciplinary research — like any research — cannot be fully formalized. Most institutes have some kind of policy to facilitate informal communication: for example by keeping interdisciplinary teams small; reducing the local distance between cooperating researchers; providing a coaching system mixing senior and junior researchers; or by allowing for opportunities for face-to-face interaction and other transfers of tacit knowledge.

The analysis finally shows that the project level is particularly relevant for the organization of interdisciplinary research. There are two 'micro-political' strategies common to the institutes of our sample. First, some institutes adapted their hiring procedures and personnel development strategies to the interdisciplinary settings, for example, watching carefully over the composition of interdisciplinary teams. In these institutes, disciplinary qualities are important but not decisive qualifications. Soft skills, such as communicative qualities or altruistic attitudes, are at least as relevant. Also, management and coordination experience are particularly valuable in interdisciplinary projects. In other words: the infrastructural and administrative 'overhead' of interdisciplinary projects is often greater than in disciplinary projects. These higher costs mean that some institutes, in particular smaller ones, struggle to provide the necessary resources for interdisciplinary research.

Notes

1. The study was financed by the German Federal Ministry for Education and Research (BMBF) and carried out by a

research group at the Social Science Research Center in Berlin (WZB). The complete results are published in Röbbecke *et al*, 2004.

2. For a detailed account, including more extended descriptions of the day-to-day practices of interdisciplinary cooperation, see Röbbecke *et al*, 2004.
3. It would have been possible to group the institutes examined merely by institutional criteria, for example by affiliation to one of the four research institutions of the extra-university research sector. Three of the four big research societies do indeed represent particular research types; the Max Planck Society stands for basic research, the Fraunhofer Society for applied research and the Helmholtz Association for a big science approach. However, these clear orientations are currently in flux: the Max Planck Society, for example, is increasingly stressing the social relevance of its research; the Fraunhofer Society is trying to improve its status in academe by applying increasingly for basic research funding. Moreover, the diversity of research orientations within these four extra-university pillars is greater than the differences between them. Thus, some institutes of our sample had more in common with particular institutes from different pillars than with the typical institute from their own pillar. Grouping institutes in terms of institutional affiliation would hence have made little sense.
4. The situation is better in climate change research, where in recent years several journals have been launched with an explicitly interdisciplinary scope. Also in our interviews, researchers from climate research institutes agreed that there was no fundamental obstacle to publishing articles with an interdisciplinary background in renowned academic journals.

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